

**DRAFT
TOTAL MAXIMUM DAILY LOAD (TMDL)**

For

Siltation, Turbidity, and Habitat Alteration

In Shades Creek

Jefferson County, Alabama

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TMDL SUMMARY / SIGNATURE SHEET

Siltation, Turbidity, and Habitat Alteration / Shades Creek Jefferson County, Alabama HUC 03150202

The TMDL for Shades Creek satisfies the 1998 consent decree obligation established in the matter of Edwards W. Mudd, II et al. v. John Hankinson et al. (Civil Action Number CV-97-S-0714-M) and Alabama Rivers Alliance, Inc. v. John Hankinson et al. (Civil Action Number CV 97-S-2518-M). This TMDL addresses impairment due to siltation, turbidity, and habitat alteration.

The data used to develop the TMDL is based on an extensive field study conducted by staff from the Channel and Watershed Processes Research Unit (CWP) of the U.S. Department of Agriculture (USDA), Agricultural Research Service, National Sedimentation Laboratory during the winter and spring of 2003. The Storm Water Management Authority (SWMA) routinely collects suspended sediment data on Shades Creek and provided this data to the project. The overall objective of the CWP study was to determine sediment yields in the Shades Creek watershed and to compare these to “reference” sediment yields for unimpaired streams in the Ridge and Valley Ecoregion supportive of the Fish and Wildlife designated use. Watershed reconnaissance, channel surveys, sampling and testing of streambed and bank sediments, and rapid geomorphic assessments were conducted along the entire length of Shades Creek.

In the absence of a numerical target, suspended-sediment loads and bed-material characteristics along Shades Creek are compared to unimpaired streams in the region. Sediment conditions in these unimpaired streams are termed “reference” streams or reaches. By reducing suspended-sediment loads in Shades Creek to conditions in reference streams in the ecoregion, water quality standards should be achieved.

In the Shades Creek watershed, sediment entrained from channel bank failures are blamed as a contributor to fine-grained sediment deposition on channel beds. CWP developed a numerical model of Shades Creek using the AnnAGNPS watershed model and the channel evolution model CONCEPTS to quantify sources of sediment from upland areas and instream processes. Model results from current and future scenarios indicate that about 33 percent of the sediment in Shades Creek originates from overland runoff and 67 percent from channel bank failure and bed erosion.

In the southwest portion of the Shades Creek watershed, two NPDES facilities are permitted to discharge sediment to Mud Creek, a tributary to Shades Creek. The contribution of suspended-sediment load from these facilities is negligible compared to sediment from non-point sources. Shades Creek is in the Birmingham/Jefferson County Municipal Separate Storm Sewer System (MS4) area. SWMA routinely collects water quality data in Shades Creek and has documented the effectiveness of best management practices (BMPs) to reduce sediment loadings to the stream. SWMA provided much of the water quality data used in the TMDL.

The TMDL is expressed in terms of mean annual yield in metric units of Tonne (T) per year per square kilometer (km^2). Based on limited historical sediment transport data available for Shades Creek, the mean annual suspended-sediment yield is 52.6 T/yr/km^2 . As a comparison, the mean annual suspended-sediment yield for “reference” streams in the Ridge and Valley Ecoregion is 24.7 T yr/km^2 . A 53 percent reduction in suspended-sediment yield is necessary to reduce sediment yields in Shades Creek to conditions in unimpaired streams in the ecoregion.

A “reference” bed-material composition is presented for streambeds dominated by coarse-grained materials (i.e., gravels). An analysis of bed materials addresses those reaches identified during the field study as impaired due to siltation by evaluating the percentage of fine-grained materials (sands and fines) embedded in gravel or gravel/cobble dominated streambeds. Coarse-grained reaches are identified because streams designated as impaired due to siltation impact spawning habitats and other biological life functions by clogging interstitial spaces in gravel/cobble beds. The target for embeddedness (i.e., sediment finer than 2 mm) in coarse-grained reaches of Shades Creek is 13.4 percent. This value is within the range of embeddedness reported for unimpaired streams in the Ridge and Valley (16.6%) as well as in the literature.

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1. Introduction

Total Maximum Daily Loads (TMDLs) are required for impaired waters on a State's Section 303(d) list as required by the Federal Clean Water Act Section 303(d) and implementing regulation 40 CFR 130. A TMDL establishes the maximum amount of a pollutant a waterbody can assimilate without exceeding the applicable water quality standard. The TMDL then allocates the total allowable load to individual sources or categories of sources through wasteload allocations (WLAs) for point sources, and through load allocations (LAs) for non-point sources. In the TMDL, the WLAs and LAs provide a basis for states to reduce pollution from both point and non-point source activities that will lead to the attainment of water quality standards and protection of the designated use.

The TMDL for Shades Creek satisfies the 1998 consent decree obligation established in the matter of Edwards W. Mudd, II et al. v. John Hankinson et al. (Civil Action Number CV-97-S-0714-M) and Alabama Rivers Alliance, Inc. v. John Hankinson et al. (Civil Action Number CV 97-S-2518-M), requiring TMDLs be developed in accordance with a specified schedule. The TMDL schedule is based on Alabama's 1996 §303(d) List. Fifty-five miles of Shades Creek, from its source to the Cahaba River, is non-supporting of the Fish and Wildlife (F&W) designated use, therefore, was placed on the State of Alabama's 303(d) list. The TMDL for Shades Creek addresses impairment due to siltation, turbidity, and habitat alteration.

The Shades Creek TMDL is based on an extensive study conducted during the winter and spring of 2003 by the Channel and Watershed Processes Unit (CWP) of the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS), National Sedimentation Laboratory in Oxford, MS. The Storm Water Management Authority (SWMA) of Birmingham provided suspended-sediment data collected on Shades Creek and personnel to assist with the field study. The first component of the CWP study was conducted in the field with overall objective to determine sediment yields in the Shades Creek watershed and to compare these to "reference" sediment yields for unimpaired streams in the Ridge and Valley Ecoregion.

A second component of CWP study was the development of numerical models to quantify sediment sources from both upland areas and instream processes. Water and sediment contributions from uplands areas can be obtained with the ANNualized AGricultural Non-Point Source (AnnAGNPS) modeling system (Bingner and Theurer, 2001). This information is also supplied as the boundary conditions used to determine the channel contributions from main channel streambeds and banks using the CONsevation Channel Evolution Pollutant Transport System (CONCEPTS) model (Langendoen, 2000). Results of the AnnAGNPS and CONCEPTS models are presented in the TMDL; details of the models are available in a separate modeling report prepared by CWP.

2. Watershed Characterization

Shades Creek is located in the upper portion of the Cahaba River Basin in Ecoregion 67, Ridge and Valley. The drainage area of the watershed, as measured from the headwaters to the confluence of the Cahaba River, is approximately 357 square kilometers (138 square miles). From the headwaters in northeastern Jefferson County, Alabama, Shades Creek flows through urban areas south of Birmingham to its confluence with the Cahaba River near the Shelby and Bibb County lines (see Figure 1). Land use distribution in the Shades Creek watershed is shown in Figure 2. Based on 2001 land use, 13 percent of the watershed is urban and the remainder is forest and pasture.

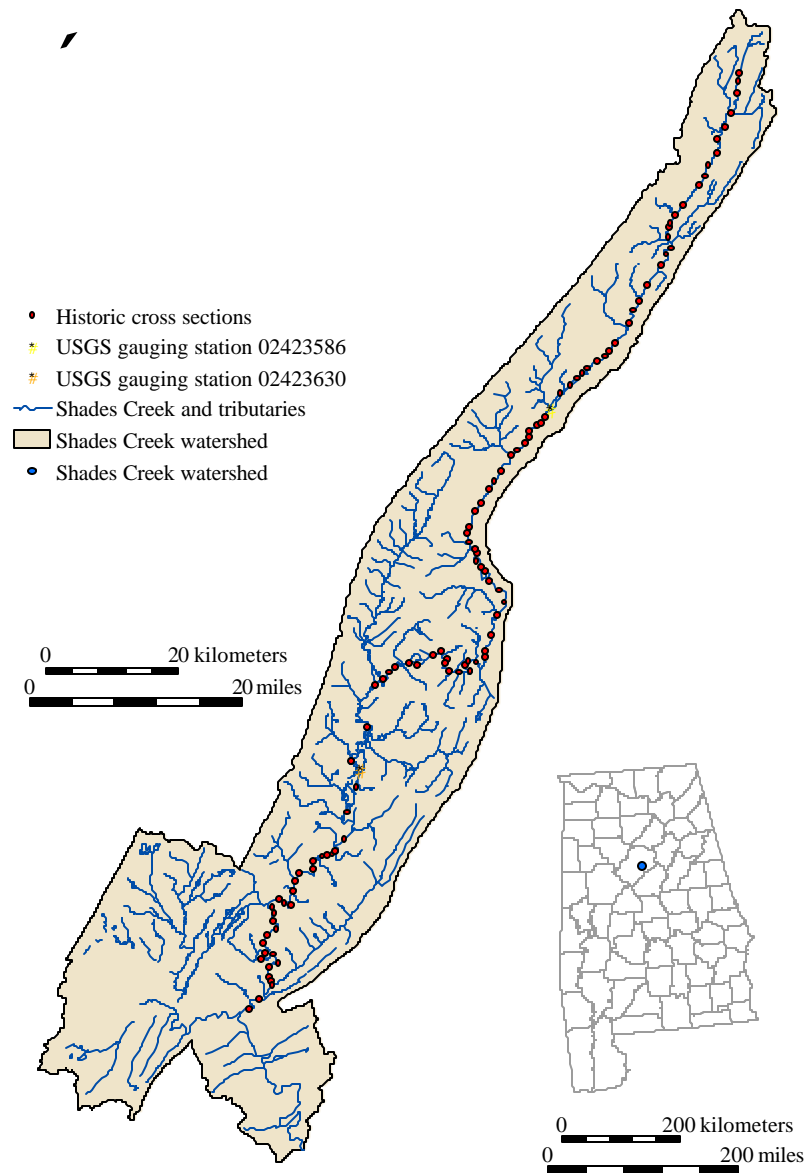


Figure 1. Shades Creek watershed showing locations of historical surveys that were used for sampling and rapid geomorphic assessments (RGAs)

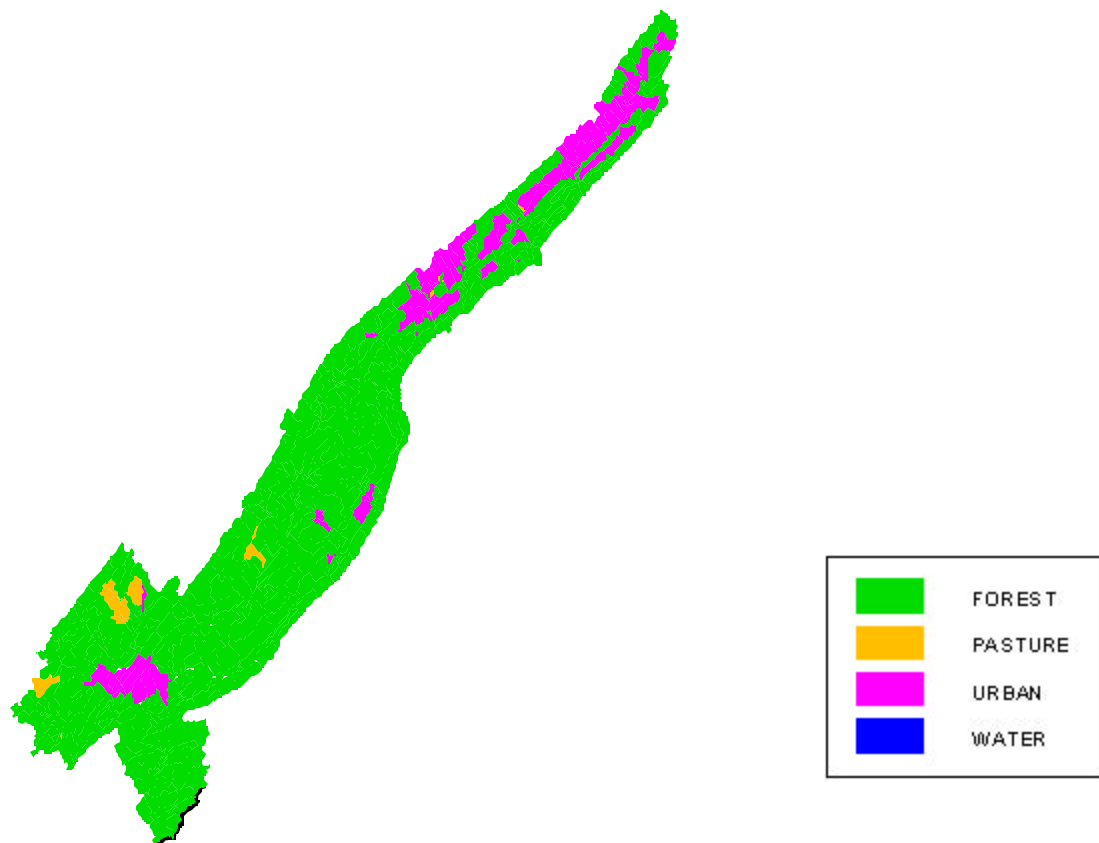


Figure 2. Land cover distribution in the Shades Creek watershed

As part of the CWP field study, Rapid Geomorphic Assessments (RGAs) were conducted at 105 sites along Shades Creek to determine relative channel stability and stage of channel evolution (see Appendix A). The RGA procedure consists on four steps: photographing upstream, downstream, and across the reach; sampling bed material, observing channel conditions and diagnostic criteria listed on the channel stability ranking scheme (example form included in Appendix A); and survey channel gradient, or water-surface slope if channel is too deep to wade. Results of the RGAs are shown in Figure 3. In terms of channel stability, values of 20 or greater are indicative of instability; values below 10 are indicative of stability. The mean index for Shades Creek was about 14, indicative of low to moderate instabilities. Bank failures are relatively common with about one third of all banks failing (see Figure 3).

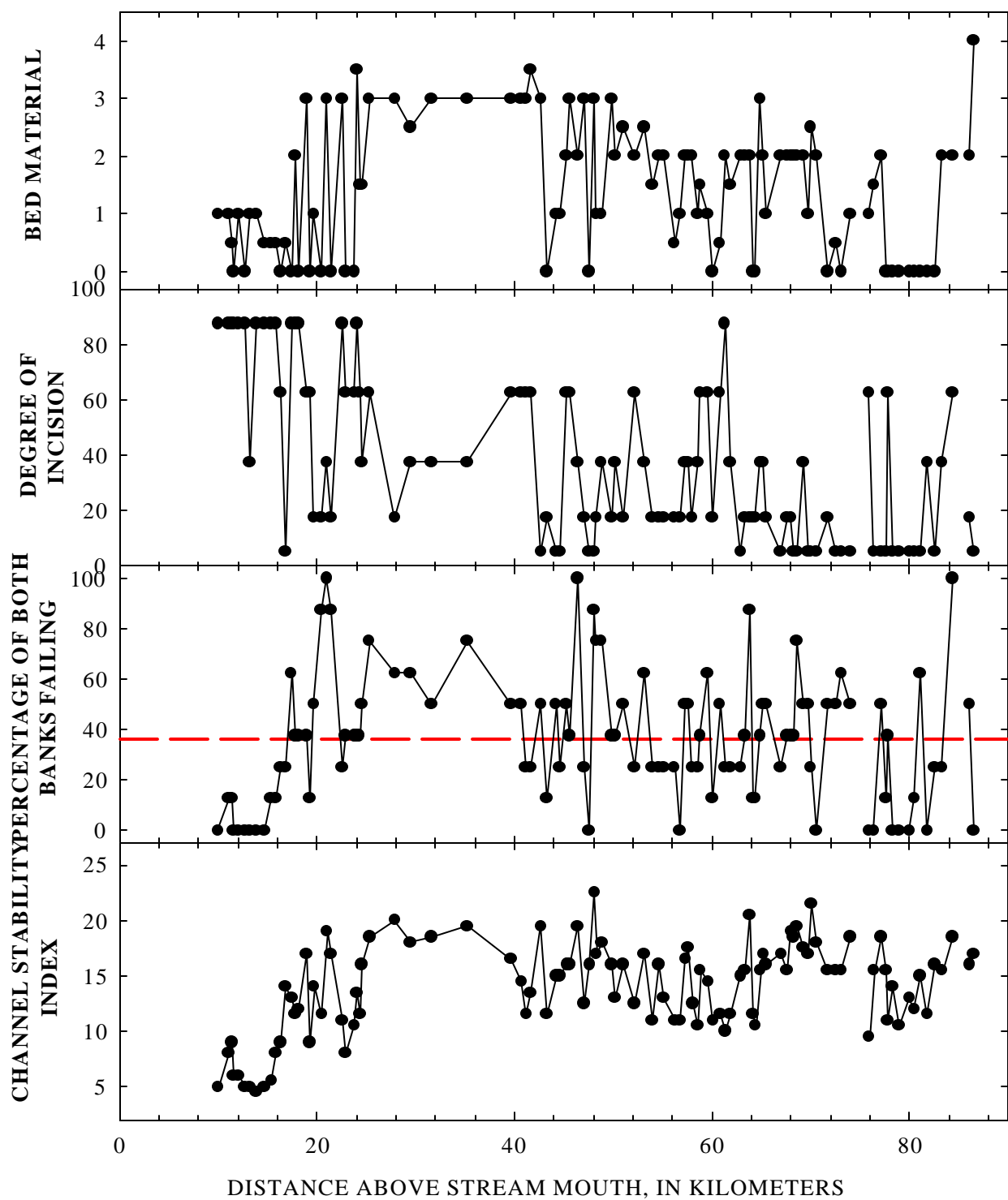


Figure 3. Longitudinal trends from RGAs in Shades Creek. Ordinate values on plots refer to RGA ranking scheme. Dotted line indicated average length of observed banks that are failing (36%).

A conceptual model of channel evolution was used on Shades Creek to characterize varying stages of channel modification through time (Simon and Hupp, 1986; Simon, 1986b). Stage I, undisturbed conditions, is followed by the construction phase (Stage II) where vegetation is removed and/or the channel is modified significantly. Degradation (Stage III) follows and is characterized by channel incision which leads to an increase in bank heights and angles until critical conditions of the bank material are exceeded, and the banks fail by mass-wasting processes (Stage IV). Sediments eroded from upstream degrading reaches and tributary streams are deposited along low gradient downstream reaches. This process is termed aggradation and begins in Stage V, which continues until stability is achieved through a reduction in bank heights and bank angles. Stage VI (restabilization) is characterized by the relative migration of bank stability upslope (as determined by establishing woody-riparian species), point-bar development, and incipient meandering. Stages I and VI represent two true “reference” conditions.

Results of the RGAs in Shades Creek identified 41 of the 105 cross sections as stable based on channel evolution and relative channel stability. Of the 41 stable sections, 19 stage I sites were identified, mostly along the downstream-most reaches and coincide with beds composed of bedrock. In addition, 22 stage VI sites were identified and are indicative of where Shades Creek has recovered from disturbances.

In addition to characterizing the streams using RGA techniques, bulk samples of bed materials were collected to determine the degree of fine-sediment deposition where beds were dominated by gravels and/or cobbles. Deposition of fine-grained sediment (silts, clays and sands) is one of the main concerns along Shades Creek because of the potential filling of interstitial spaces in gravel and cobble beds. This condition is described as embeddedness, and is generally represented by the percentage of material finer than 2mm within a coarser matrix of gravels and/or cobbles. The frequency of bed material types found on Shades Creek is shown in Figure 4. Of the 102 sites sampled for bed material along Shades Creek, 53 are considered coarse-grained (dominated by gravel or larger clasts), 30 bedrock, and 19 fine grained (dominated by sand or finer clasts). In terms of overall stream lengths, 32% of the reach contains bedrock beds, about 41% has coarse-grained beds, and 27% has fine-grained beds.

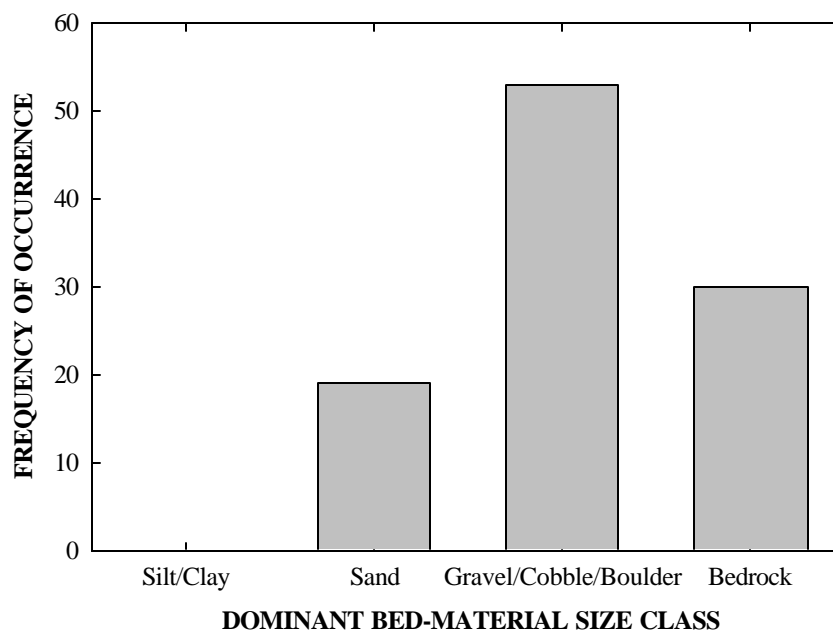


Figure 4. Frequency of bed material types in Shades Creek

3. Target Identification

The Alabama 1998 303(d) List identifies Shades Creek as having impaired conditions to support Fish and Wildlife (F&W) designated use due to turbidity, siltation and habitat alteration. Impairment due to turbidity refers to excessive amounts of fine-grained materials being transported in the water column. Impairment due to siltation implies that deposition of fine-grained materials on the channel bed has hampered oxygenation of coarser bed material (gravels and cobbles), creating poor habitat for aquatic organisms.

Surveys conducted by ADEM between 1990 and 1993, and again in 1997 indicated impairment due to the following reasons: collection system failure, highway/road/bridge construction, land development, urban runoff, removal of riparian vegetation, and bank/shoreline modification. Collection system failures may have been a historical source of sediment but is currently unlikely, as the Shades Valley Waste Water Treatment Plant (WWTP) has been closed. The 1.8 million linear feet of sewer servicing the Shades Creek basin is connected to the Valley Creek WWTP which discharges to Valley Creek.

3.1 Numerical Target

Water quality criteria for the fish and wildlife use classification are described in ADEM Admin. Code R. 335-6-10-.09(5)(9). The criteria does not contain a numerical target for sediment but is in narrative form for turbidity:

“there shall be no turbidity other than natural origin that will cause substantial visible contrast with the natural appearance of waters or interfere with any beneficial uses which they serve. Furthermore, in no case shall turbidity exceed 50 Nephelometric units above background. Background will be interpreted as the natural condition of the receiving waters, without the influence of man-made or man-induced causes. Turbidity levels caused by natural runoff will be included in establishing background levels”.

3.2 Target Selection

In the absence of a numerical target, suspended-sediment loads and bed-material characteristics along Shades Creek are compared to unimpaired streams in the region. Sediment conditions in these unimpaired streams are termed “reference” streams or reaches. One of the objectives of the CWP study was to determine applicable suspended-sediment “reference” condition and sediment yield for the Ridge and Valley Ecoregion and apply it to conditions along Shades Creek using geomorphic techniques and historical data from the U.S. Geological Survey gauging station on Shades Creek near Greenwood, Alabama.

To compare loadings between impacted and reference conditions, a common discharge rate is required. In previous studies conducted by the CWP, the “effective discharge” serves as a useful indicator of regional suspended-sediment transport conditions for “reference” and impacted sites. The effective discharge is typically defined as the discharge or range of discharges that shape channels and transport the most sediment. In many parts of the US, the effective discharge is approximately equal to the peak flow that occurs on average, about every 1.5 years ($Q_{1.5}$; Andrews, 1980; Andrews and Nankervis, 1995), and may be analogous to the bankfull discharge in stable streams. Detail calculations of effective discharge for streams in the Ridge and Valley Ecoregion are provided in Simon et al.(2003).

There were 68 sites in the Ridge and Valley where sufficient flow and suspended-sediment data were available to calculate the sediment load at $Q_{1.5}$ discharge. To normalize the data for watersheds of different size, the sediment load is divided by drainage area to obtain sediment yield (in $T/d/km^2$). The median suspended-sediment yield value at the $Q_{1.5}$ for all sites in the Ridge and Valley is $2.78 T/d/km^2$ (see Figure 5). This is placed in a national context in Figure 6 where median values for most of the 84 ecoregions in the continental United States are shown. The median concentration for the Ridge and Valley, also at the $Q_{1.5}$ is 162 mg/l. In terms of mean annual suspended-sediment yield and concentration, values obtained from all sites in the Ridge and Valley is $24.7 T/yr/km^2$ and 45.1 mg/l, respectively. The target for the Shades Creek TMDL is expressed in terms on the mean annual suspended sediment load and concentration.

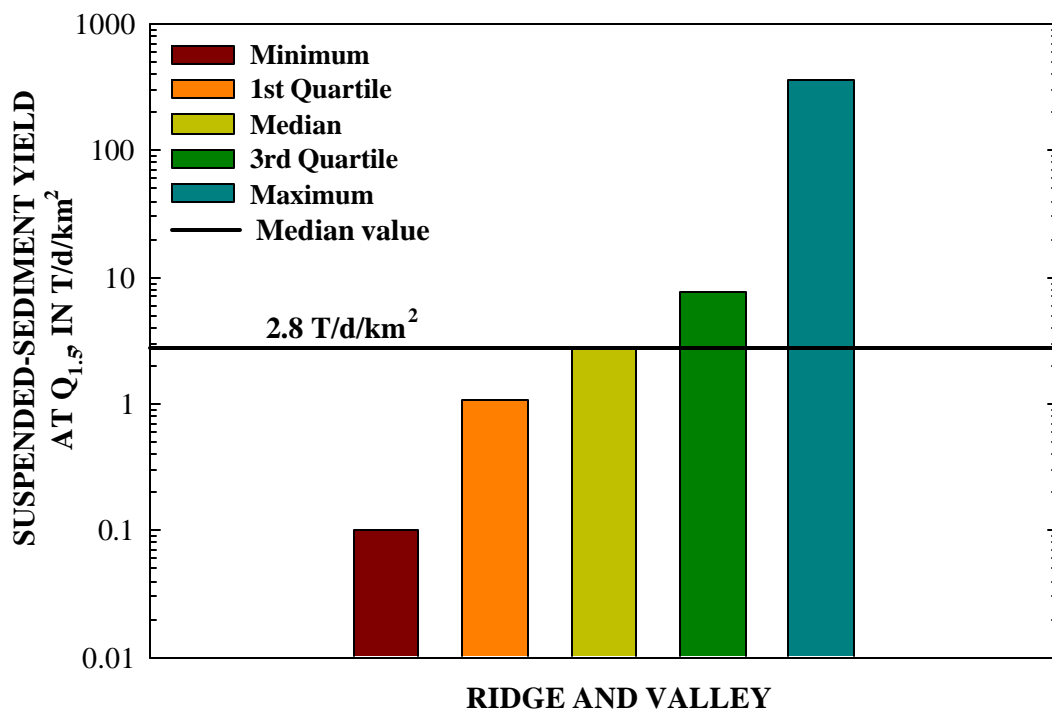


Figure 5. Distribution of suspended-sediment yield at the $Q_{1.5}$ for the Ridge and Valley Ecoregion.

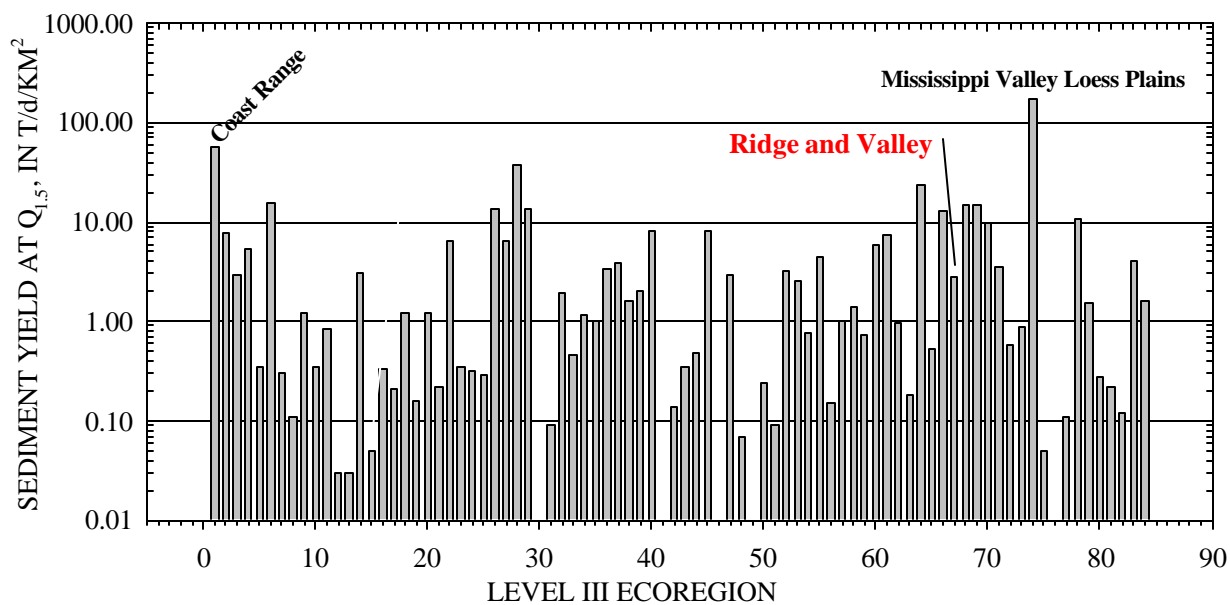


Figure 6. Comparison of median suspended-sediment yields at the $Q_{1.5}$ for 84 ecoregions of the continental United States. Modified from Simon *et al.*, 2002.

4. Source Assessment

A TMDL evaluation examines the known potential sources of the pollutant in the watershed, including point sources, nonpoint sources, and background levels. For the purpose of these TMDLs, facilities under the National Pollutant Discharge Elimination System (NPDES) Program are considered point sources.

4.1 Point Sources

There are two WWTP located on Mud Creek, a tributary to Shades Creek in the southwest portion of the watershed (see Figure 1). Tannehill State Park Lagoon (NPDES AL0056359) and East Tuscaloosa-West Jefferson WWTP (NPDES AL0068420) are permitted to discharge municipal waste. In general, sediment loads from point sources are negligible in relation to the nonpoint sources. In addition, sediment from point sources are generally composed of organic material and would provide less direct impact to biological integrity than would direct soil loss to the streams. Permit information and calculated wasteload allocations (WLA) for NPDES facilities are shown in Table 1.

Table 1. Continuous discharge NPDES facilities in Shades Creek watershed

Facility	NPDES No.	Design Flow (mgd)	TSS Limit (mg/l)	WLA (Tonne/day)
E. Tuscaloosa-W. Jefferson STP	AL0068420	0.8	30	0.09
Tannehill State Park Lagoon	AL0056359	0.08	90	0.03

Note: WLA calculated as follows: flow (mgd) * concentration(mg/l) * 8.345/2204.623 = tonne/day (e.g., 0.8*30*8.345 = 200 lb/day = 0.09 tonne/day)

Large and medium Municipal Separate Storm Sewer Systems (MS4s) serving populations greater than 100,000 people are required to obtain an NPDES storm water permit. At present, Jefferson County/City of Birmingham and 22 other municipalities are included in one MS4 permit regulated by the NPDES program (ALS000001). In March 2003, EPA initiated Phase II MS4 permits for municipalities of 50,000 people. Currently, Sylvan Springs is the only Phase II municipality to join the SWMA program (personal correspondence with SWMA, 2003).

The upper Shades Creek watershed, from the headwaters to the Jefferson County line, is within the MS4 permit area (personal correspondence with SWMA, 2002). Discharges from MS4s occur in response to storm events. During rain events, sediment originating from construction activities and urban areas is transported to the stream through road drainage systems, curb and gutter systems, ditches, and storm drains. The MS4 permit requires quarterly collection of water quality samples at select locations and times.

Samples are analyzed for metals, cyanides, phenols, and conventional pollutants including suspended sediment. As part of the MS4 permit, SWMA has an Erosion and Sediment Control Ordinance to control discharges of storm water and non-storm water discharges to the MS4 from lands on which land-disturbing activities are conducted.

ADEM requires an NPDES permit for construction activities of one acre or greater in size. The permit requires a Construction Best Management Practices Plan (CBMPP) be designed for the site and fully implemented and maintained to minimize pollutant discharges in stormwater runoff to the maximum extent practicable during land disturbance activities. Details of the requirements of ADEM's NPDES construction permit can be found in ADEM Admin. Code 335-6-12.

4.2 Nonpoint Sources

Nonpoint sources of sediment can potentially include roads, bare ground (i.e., non-permitted construction type sites, etc.), and sheet and rill erosion from uplands and agricultural fields, gullies, and streambeds and banks. The adjustment of channel width by mass-wasting and related processes represents an important mechanism of channel response to increased streamflow. Sediment entrained from bank failures are blamed as a contributor to fine-grained sediment deposition on the streambed. Stream bank failures occur when erosion of the bank toe and the channel bed adjacent to the bank have increased the height and angle of the bank to the point where gravitational forces exceed the shear strength of the bank material. After failure, bank materials may be delivered directly to the flow and deposited as bed material, or dispersed as wash load, or deposited along the toe of the bank as intact blocks, or as smaller, dispersed aggregates (Simon et al., 1991). AnnAGNPS and CONCEPTS modeling were conducted to provide insight on sediment sources. Model results indicate that about one-third of the sediment entering Shades Creek is from overland runoff and about two-thirds is from instream processes.

5. Data Collection

As described in the Watershed Characterization section, collection of field data was required to characterize channel, upland, and sediment-transport condition and provided input parameters for the CONCEPTS model. This section of the report describes the data collected and computational techniques used to compute existing and reference suspended-sediment transport loadings.

Data were collected at 105 cross-sections over 76.4 km of Shades Creek from the headwaters to approximately 10 km above the confluence with the Cahaba River. The cross section locations coincided with locations surveyed in 1978 as part of a flood-hazard study. At each cross section, RGAs were conducted and samples of bed, bank, and bank-toe materials were collected and tested.

In Shades Creek *in situ* bank-toe materials are composed of a wide range of materials ranging from silts and clays to bedrock. To measure streambank stability *in situ* devices such as the borehole shear test and the submerged jet-test device were utilized in the field. The advantage of using *in situ* devices is that the test can be carried out on undisturbed soils and at various depths to locate weak strata. In cases where bank-toe material is fine-grained alluvium a submerged jet-test device was used to measure the critical shear stress (i.e., stress where there is no erosion) and erodibility coefficient. In cases where bank-toe material is composed of coarse-grained materials, samples were collected and published values for the critical shear stress were assigned (Julien, 1995). The shear strength of the bank materials was determined at various depths using the borehole shear device. Results of the bank stability measurements were used to represent the cross section for input to the CONCEPTS model.

5.1 Suspended-Sediment Data

Suspended-sediment data were available for Shades Creek near Greenwood, AL (USGS station 02423630) from the USGS and from the Stormwater Management Authority (SWMA). When used in conjunction with the instantaneous discharge at the time of sample collection, sample data was used to compute suspended-sediment transport rates. Integration with continuous flow records allows annual suspended-sediment loads to be calculated.

In the Ridge and Valley, 74 sites in seven states have at least 30 matching samples of suspended sediment and instantaneous flow discharge. Of the 74 sites, 56 gauging stations had sufficient mean-daily flow data to calculate annual suspended-sediment loads. Flow data were downloaded from the USGS web site and discharge values were converted from ft^3/s to m^3/s . Daily loads were calculated for each gage by applying the appropriate rating equation to the mean discharge for each day, giving a suspended-sediment load in metric units of T/d. Daily-load values were summed by calendar year and divided by drainage area to obtain the annual suspended-sediment yield (in metric units of $\text{T}/\text{y}/\text{km}^2$) for each year of flow record. Mean annual suspended-sediment yields were calculated by dividing by the number of years of complete flow record. An annual concentration (in mg/l) was calculated for each station-year of record by dividing the suspended-sediment load by the total volume of water during the year. A mean-annual concentration was obtained by summing the annual concentrations and dividing by the number of years of complete flow record.

5.2 Suspended-Sediment Transport Rating

Suspended-sediment data were evaluated in two ways:

1. At a single flow rate, representing a channel-forming or “effective discharge”, and
2. As an integration of all mean-daily flows to determine mean-annual suspended-sediment loads, yields, and concentrations.

Both of these techniques rely initially on a relation between flow and suspended-sediment concentration or load at a given site. For establishing sediment-transport relations, instantaneous concentrations and 15-minute flow data were used from USGS gauging station records while mean-daily flow values were used to calculate annual loads and yields.

A daily load was calculated for each sample using the following formula:

$$L = 0.0864 C Q \quad (1)$$

where: L = load in T/d;

C = instantaneous concentration, in mg/l; and

Q = instantaneous discharge, in m³/s.

The value 0.0864 is to convert from seconds to days and from milligrams to tonnes.

Linear regression in log-log space results in power function describing the relation between instantaneous discharge and load as:

$$L = a Q^b \quad (2)$$

where a and b are regression coefficients.

5.3 “Existing” Sediment Transport Conditions on Shades Creek

A suspended-sediment rating relation was developed for the gauge near Greenwood based on data obtained from the USGS and, more recently, from data collected by SWMA (see Figure 7). Note that both the 95% confidence limits of the regression and the 95% prediction limits are shown in Figure 7, highlighting the relative uncertainty inherent in predicting a suspended-sediment load at a given discharge. The suspended-sediment load at the $Q_{1.5}$ for Shades Creek near Greenwood is calculated to be about 1360 T/d. Normalizing the load by the drainage area results in sediment yield. For Shades Creek the equivalent yield is about 7.3 T/d/km². In terms of average annual values, the suspended sediment load at the Greenwood gage is about 9850 T/yr. Normalizing this load by the drainage area results in an average annual sediment yield of 52.6 T/y/km². The mean annual suspended-sediment concentration for Shades Creek near Greenwood is 77.6 mg/l.

Calculated suspended-sediment loads for the Shades Creek site near Greenwood may be higher than actual because of the lack of high-flow samples and the associated uncertainty in the shape of the transport rating at high flows. For example, the maximum flow rate sampled for suspended sediment at the Shades Creek gauge was 31.7m³/s compared to a discharge of 98m³/s at the 1.5-year recurrence interval. Of the 6940 mean-daily flow records used to calculate annual loads, 132 days or 1.9% had flow rates exceeding the maximum sampled discharge. We assume that the transport rating shown in Figure 7 is linear (in log-log space) through the un-sampled higher discharges. Because transport ratings often flatten at higher discharges calculations of suspended-sediment load at the $Q_{1.5}$ may be overestimated for Shades Creek. Model output from

CONCEPTS were used to compute the sediment loads at higher flows to verify this assumption.

In addition to predicting sediment loads, the CONCEPTS model also simulates discharge in the stream. As a check on the magnitude of the $Q_{1.5}$ discharge, results from CONCEPTS indicate the $Q_{1.5}$ at the Greenwood location in the model is 103 m^3/s . The simulated and estimated values for the $Q_{1.5}$ discharge are very close, and provide confidence that sediment loads estimated from the transport curve are not overestimated. The simulated suspended sediment yield at the $Q_{1.5}$ discharge at the Greenwood gage location is 10.5 T/d/km^2 . This is slightly higher than the measured value of 7.3 T/d/km^2 and is expected as CONCEPTS calculates the discharge at 10-minute intervals whereas the data reported at the USGS gage are mean daily values, which tends to be lower than instantaneous values. The average annual sediment load simulated using the CONCEPTS model for the time period 1978 through 2001 is about 8040 T/yr . The difference between measured and simulated annual average loads is about 5 percent and provides additional confidence in the using the ecoregion approach for establishing TMDL targets.

AnnAGNPS and CONCEPTS models were used to estimate the sediment contribution from the watershed and instream processes based on current (2001) land use. At the confluence of Shades Creek and the Cahaba River, the total suspended sediment load is about 21,000 T/yr , or in terms of yield, 58 T/yr/km^2 . Of this load, approximately one-third is from overland runoff and about two-thirds from the streambanks.

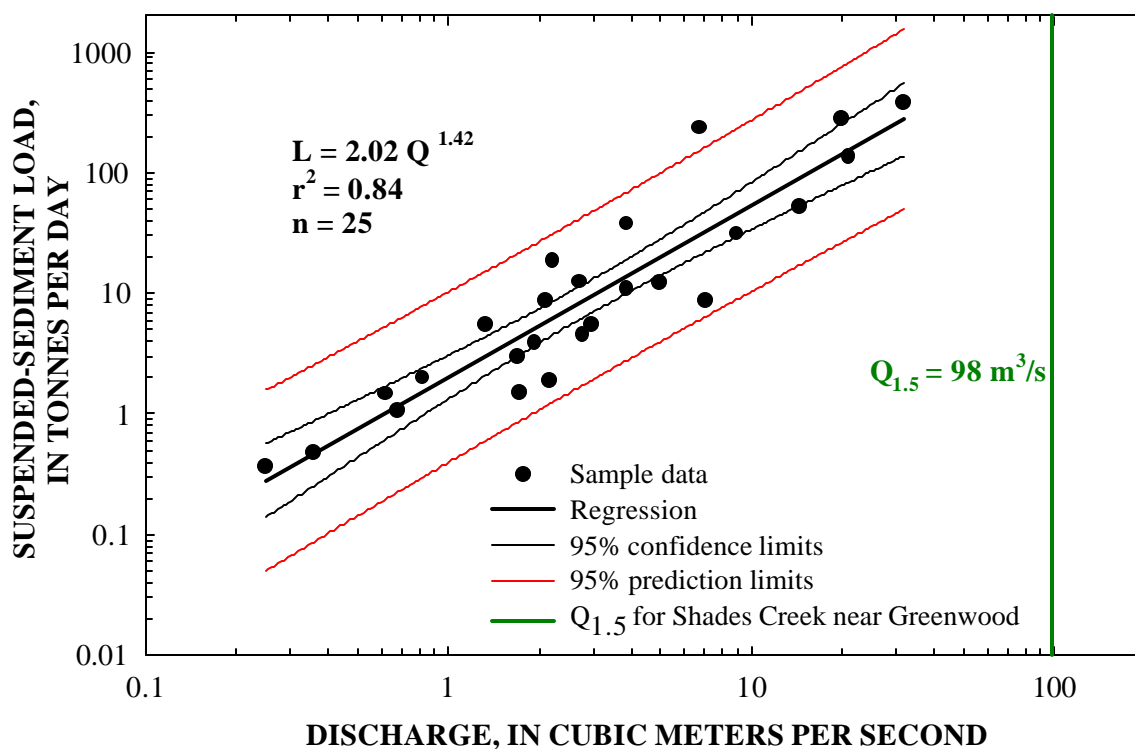


Figure 7. Suspended-sediment rating relation for Shades Creek at Greenwood, Alabama (station 02423630) showing regression statistics, confidence and prediction limits, and the $Q_{1.5}$

5.4 “Reference” Sediment Transport Conditions Using Mean-Annual Values

A suspended-sediment transport rating is developed (Porterfield, 1972; Glysson, 1987; Simon, 1989a) for each of the 74 sites in the Ridge and Valley by plotting discharge versus concentration in log-log space and obtaining a power function by regression. Figure 8 illustrates the development of sediment transport rating relationship for a stable stream in the Ridge and Valley Ecoregion. Trends of these data (in log-log space) often increase linearly and then break off and increase more slowly at high discharges. Preliminary analyses show that although sand concentrations continue to increase with discharge, the silt-clay fraction attenuates, causing the transport relation to flatten. A transport rating developed with a single power function commonly over-estimates concentrations at high flow rates, leading to errors in calculating the effective discharge. To alleviate this problem, a second or third linear (in log-log space) segment is sometimes developed with the upper end of data set (see Figure 8). The division point between these data ranges was identified by eye, and a manual iterative procedure was carried out to ensure the division point was optimal.

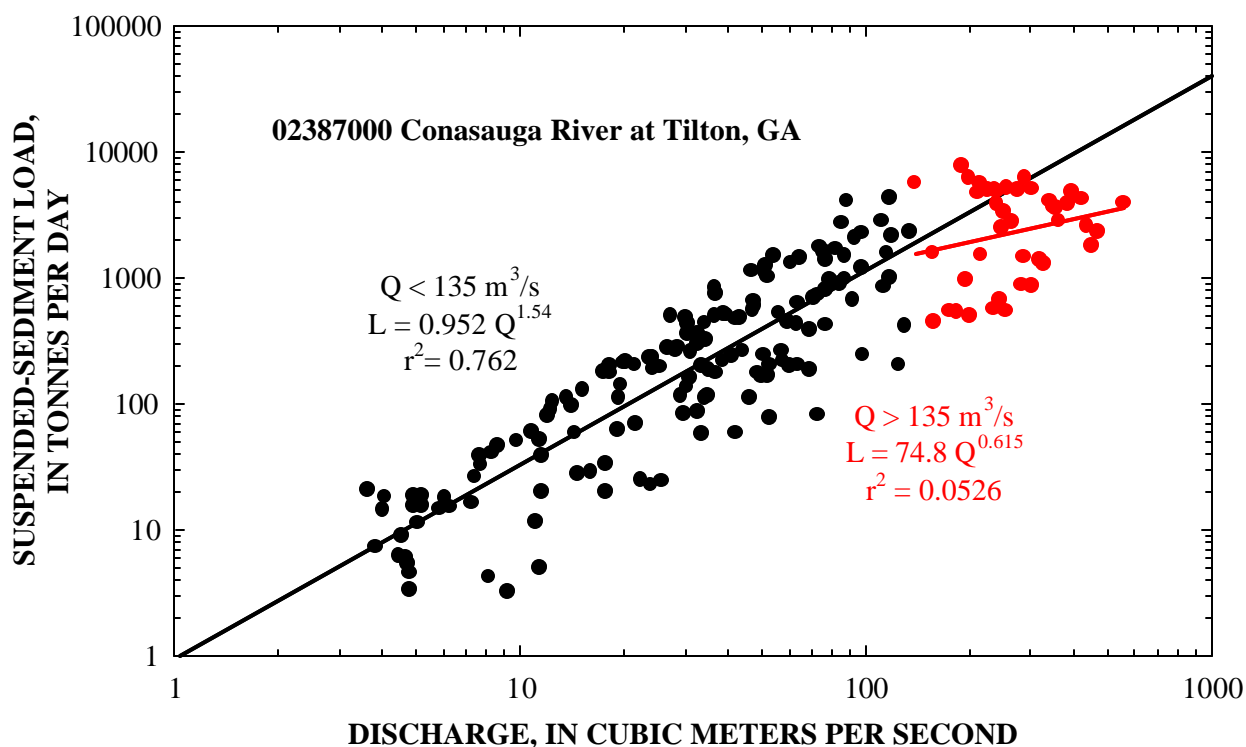


Figure 8. Development of suspended-sediment rating relation in log-log space showing potential error at high discharges without incorporating a second linear segment.

Annual suspended-sediment yields were calculated for all sites with available data in the Ridge and Valley using mean-daily flow data and the suspended-sediment transport relations described above. Mean annual suspended-sediment yield and concentration for stable/reference sites in the Ridge and Valley is 24.7 T/y/km² and 77.6 mg/l, respectively

Calculations of reference conditions at all sites in the Ridge and Valley are included in Simon (2003).

A comparison of mean annual suspended-sediment yields and concentrations for “reference” sites and unstable sites in Shades Creek are shown in

Figure 9. and Figure 10. The difference between the reference mean-annual suspended-sediment concentration and the value for Shades Creek near Greenwood is about 42 percent, and is strikingly similar to the reference yield results of 53 percent (i.e., $(52.6 - 24.7) / 52.6 * 100 = 53\%$). On Shades Creek, both the suspended-sediment yield and concentration approximate the 75th percentile of reference conditions for the Ridge and Valley, indicating that Shades Creek displays moderate impact due to sediment in the water column.

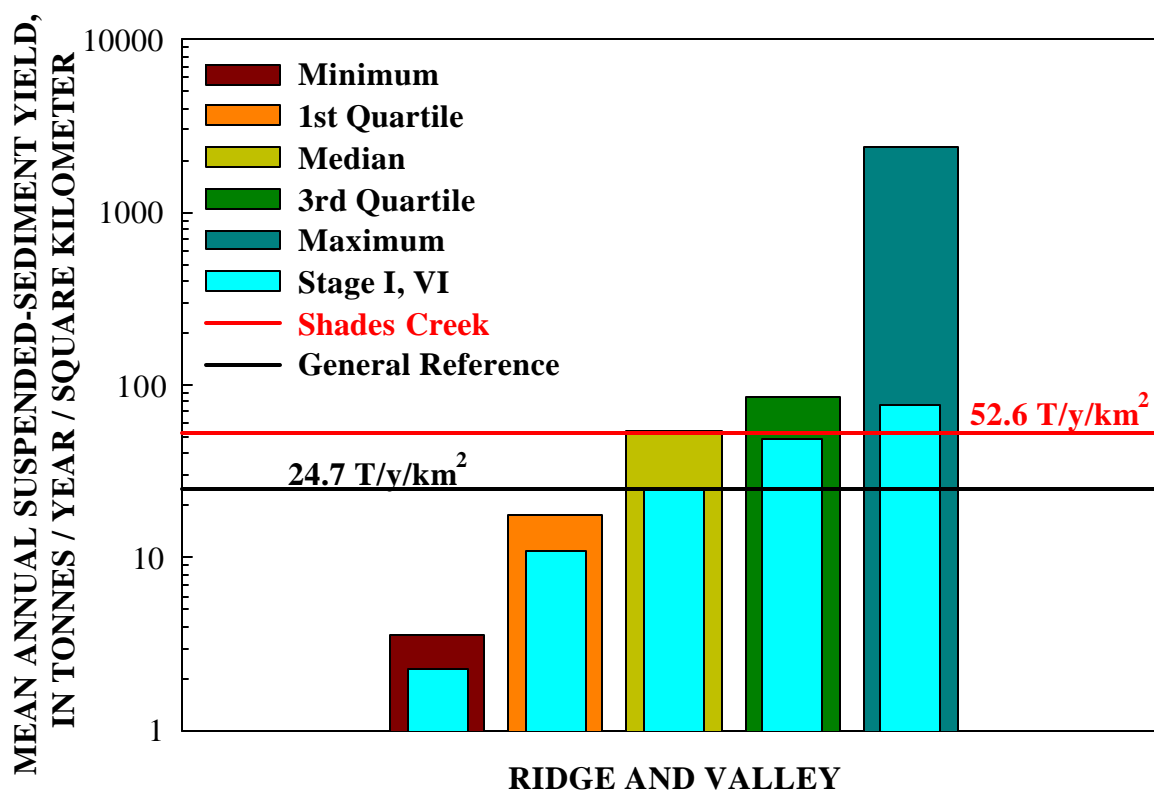


Figure 9. Comparison of mean annual suspended-sediment yield in “reference” streams in the Ridge and Valley and in Shades Creek

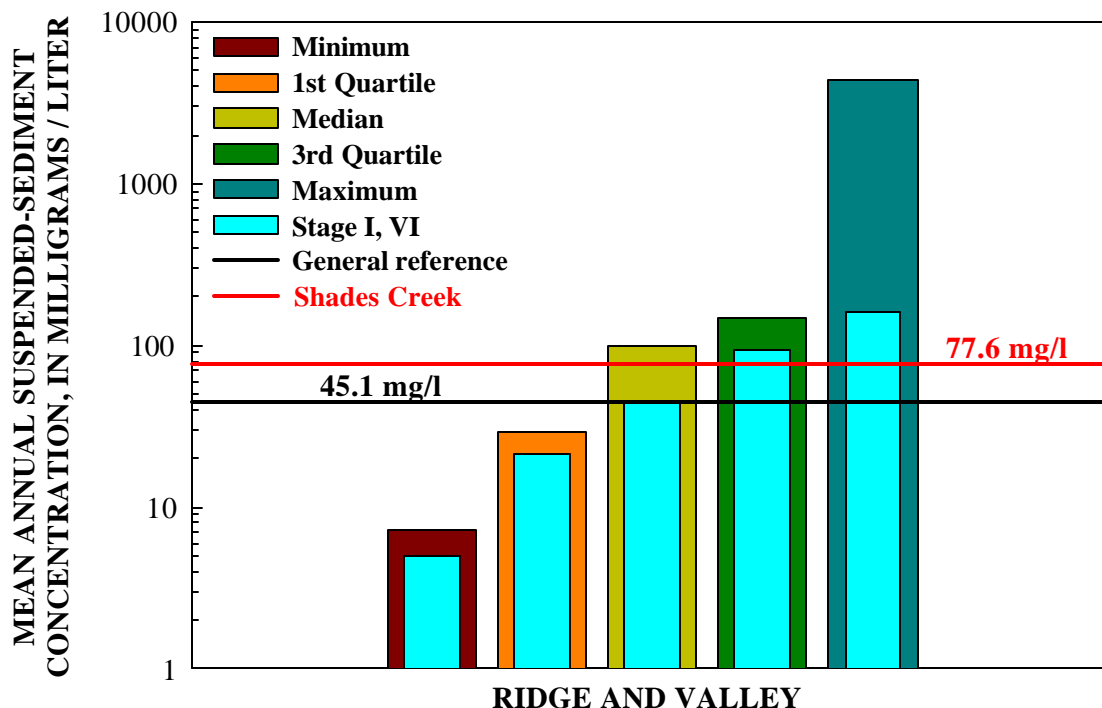


Figure 10. Comparison of mean annual suspended-sediment concentration in “reference” streams in the Ridge and Valley and in Shades Creek

5.5 “Reference” Bed Material Composition

Using the same concept for bed material as was used for suspended sediment, sites from the Ridge and Valley (Ecoregion 67) were sorted into stable and unstable sites to determine a reference bed-material composition for coarse-grained reaches. Coarse-grained reaches are singled out because streams designated as impaired due to siltation impact spawning habitats and other biologic life functions by clogging interstitial spaces in gravel-cobble beds. Because a reasonably large number of stable sites were also located on Shades Creek, reference conditions developed for the Ridge and Valley can be directly compared to reference conditions along Shades Creek itself. Reference sites on Shades Creek are designated as being Stage I or Stage VI based on the channel evolution model and are listed in Appendix A.

A reference bed-material composition is based on a measure of embeddedness; the percentage of materials finer than 2 mm (sand, silt and clay) in gravel or gravel/cobble-dominated streambeds. Bed-material data from both the Ridge and Valley and Shades Creek were filtered to include only those sites that are dominated by coarse-grained sediment (more than 50% of the streambed composed of materials coarser than 2 mm). Further sorting of the data into stable and unstable sites provided a means of comparing the degree of embeddedness in coarse-grained stream reaches. A reference value of 4%, based on the median percentage of streambed material finer than 2 mm was determined for not only the Ridge and Valley (Figure 11) but for Shades Creek as well (Figure 12).

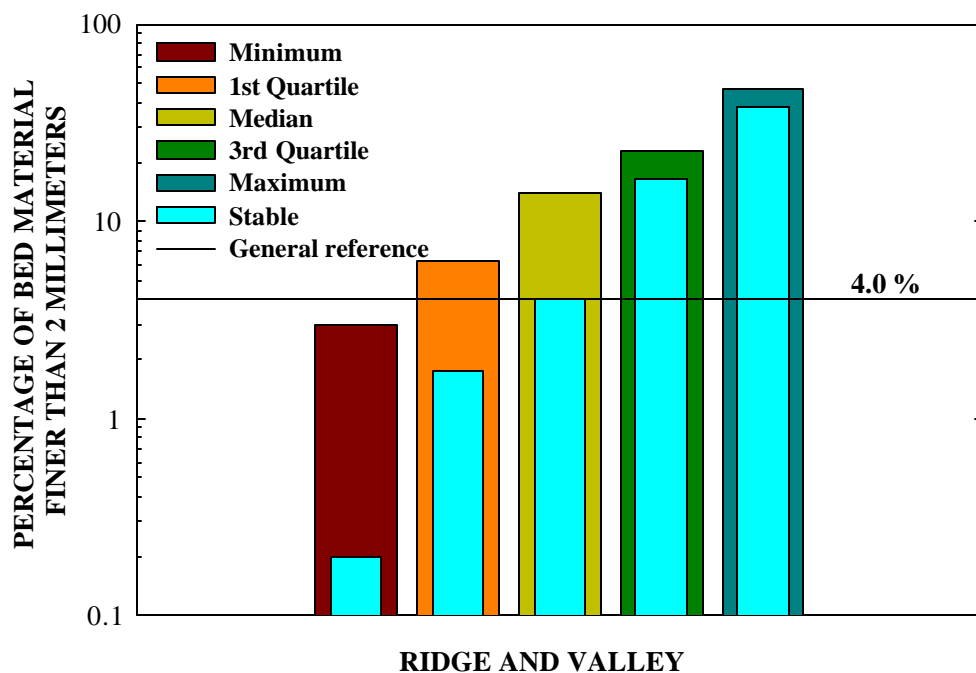


Figure 11. Comparison of percentage of bed material finer than 2 mm (sand) for “reference” and unstable sites in the Ridge and Valley

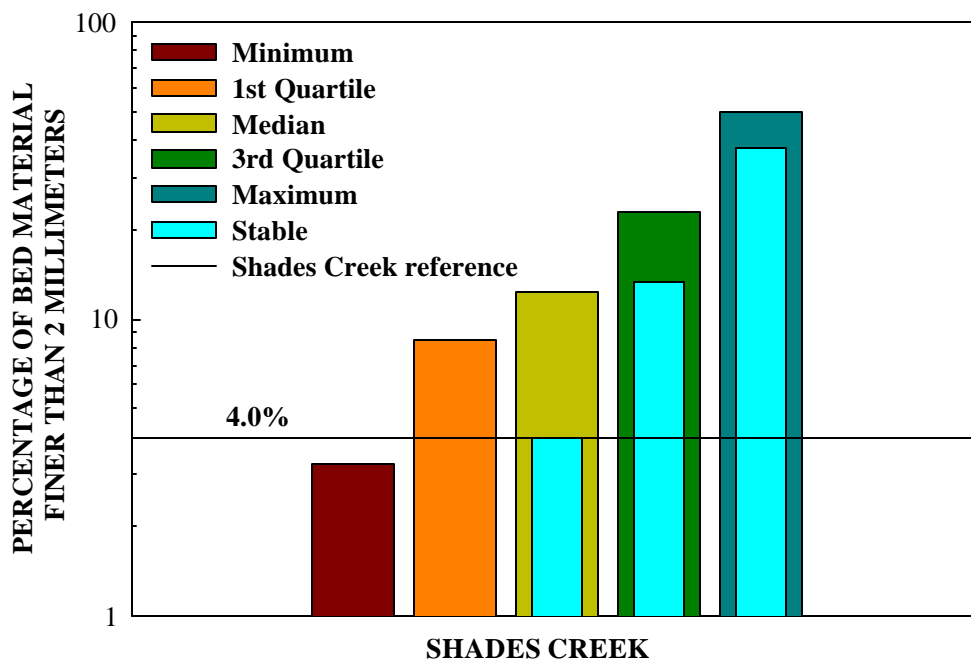


Figure 12. Comparison of percentage of bed material finer than 2 mm (sand) for stable and unstable sites in Shades Creek

A comparison of embeddedness values for “reference” and unstable sites in the Ridge and Valley and Shades Creek is shown in Table 2. It is coincidental that the median values for embeddedness are the same for both Shades Creek and the Ridge and Valley.

Table 2. Comparison of embeddedness in stable and unstable sites in Shades Creek and Ridge and Valley

Location	1 st Quartile	Median	3 rd Quartile	Inter-quartile range
Stable/reference sites				
Ridge and Valley	1.8	4.0	16.6	14.8
Shades Creek	0	4.0	13.4	13.4
Unstable sites				
Ridge and Valley	6.2	14.1	22.9	16.4
Shades Creek	8.6	12.4	23.0	14.4

It is reasonable to use the embeddedness values representing the 3^d quartile as the target for embeddedness in coarse-grained reaches as these values (13.4% for Shades Creek and 16.6% for the Ridge and Valley) are in the range of those reported in the literature (Barbour *et al.*, 1999; Kondolf, 2003). Using the reference values obtained for both the Ridge and Valley, the distribution of fine-grained sediments within coarse-grained streambeds located in Shades Creek is shown in Figure 13.

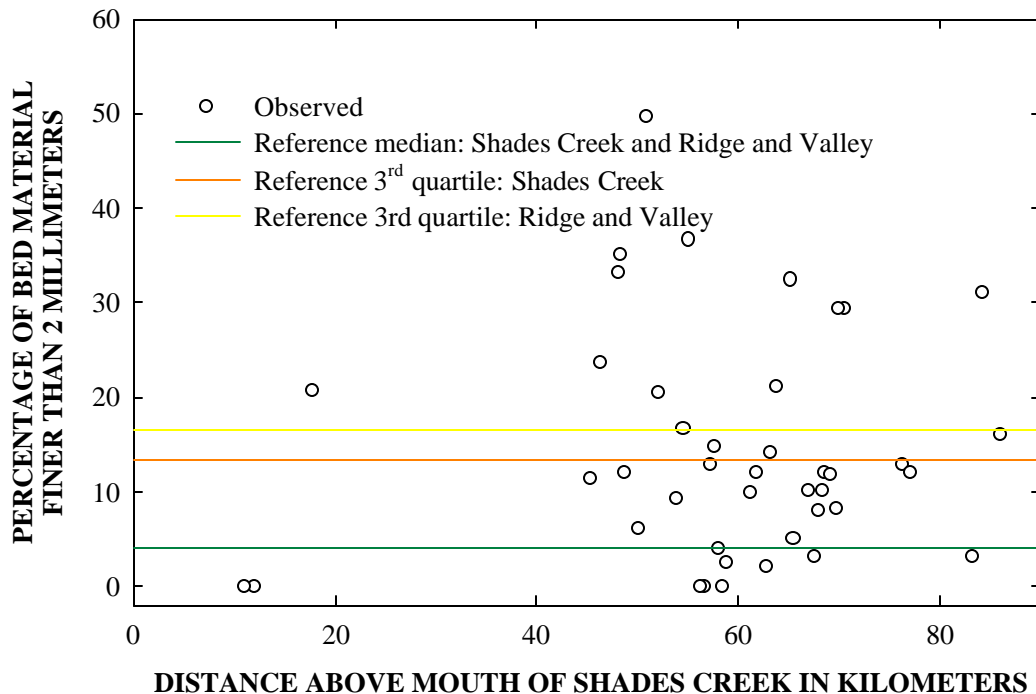


Figure 13. Longitudinal distribution of fine-grained sediments within coarse-grained streambeds

6. Total Maximum Daily Load (TMDL)

A TMDL establishes the total pollutant load a waterbody can assimilate and still achieve water quality standards. The components of a TMDL include a wasteload allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources (including natural background), and a margin of safety (MOS), either implicitly or explicitly, to account for uncertainty in the analysis. Conceptually, a TMDL is defined by the equation:

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS}$$

The TMDLs for Shades Creek is expressed in terms of average annual sediment yield, in metric units of T/yr/km², using data collected from reference streams in the Ridge and Valley ecoregion. It is acceptable for TMDLs to be expressed through other appropriate measures (e.g., sediment yield) other than mass loads per time (40 CFR 130.2).

6.1 Wasteload and Load Allocations

The WLA component for the TMDL is separated into continuous discharge and MS4 components. The continuous discharge WLA is expressed in metric units of mass loads per time (i.e., tonne/day) and is based on facility design flow (converted to metric units) and permit limits for total suspended solids (see Table 1 for WLA by facility). The WLA for the MS4 and the LA components are expressed as average annual sediment yield based on reference conditions. The reduction necessary to achieve the TMDL is based on the percent difference between existing loads measured at the Greenwood gage and mean annual sediment loads for stable streams in the Ridge and Valley. TMDL components are shown in Table 3.

Table 3. TMDL Components

WLA		LA (T/yr/km ²)	MOS	TMDL (T/yr/km ²)	% Reduction
Continuous (T/day)	MS4 (T/yr/km ²)				
0.12	24.7	24.7	Implicit	24.7	53

6.2 Margin of Safety

A Margin of Safety (MOS) is a required component of a TMDL that accounts for the uncertainty in the relationship between the pollutant loads and the quality of the receiving waterbody. The two types of MOS development are to implicitly incorporate the MOS using conservative model assumptions or to explicitly specify a portion of the total TMDL as the MOS. The MOS selected for this TMDL is explicit as conservative assumptions in the ecoregion approach provides a sufficient implicit MOS.

6.3 Critical Conditions

The average annual watershed load represents the long-term processes of sediment accumulation of sediments in the stream habitat areas that are associated with the potential for habitat alteration.

6.4 Seasonal Variation

Seasonal variation is incorporated in these TMDLs through the use of average annual loads.

7. Recommendations

Alabama has adopted the Basin Approach to Water Quality Management, a plan that divides Alabama's major drainage basins into groups. During each yearlong cycle, resources for water quality monitoring are focused in one of the basin groups. During the next monitoring phase in the Cahaba River Basin, Shades Creek will receive additional monitoring to identify any changes or improvements in water quality. Monitoring is ongoing by SWMA and provides important data during both wet and dry conditions.

In addition to collecting suspended-sediment data, biological data are needed to determine whether the degree of embeddedness as shown for stable sites is in fact a threshold for biologic communities or if the embeddedness for unstable sites is of sufficient magnitude to impair biologic function.

The application of the AnnAGNPS and CONCEPTS models as a land management tool will provide an indication of the quantity of sediment delivered to Shades Creek from upland area and instream processes. Model scenarios can then be developed to assist in identifying the best location for BMPs in the watershed.

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APPENDIX A

Field Sampling

1. Primary bed material						
	Bedrock	boulder/cobble	gravel	sand	silt/clay	
	0	1	2	3	4	
2. Bed/bank protection						
	Yes	No	(with)	1 bank	2 banks	
				Protected		
	0	1	2	3		
3. Degree of incision (Relative elev. of “normal” low water; floodplain/terrace @ 100%)						
	0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%	
	4	3	2	1	0	
4. Degree of constriction (Relative decrease in top-bank width from up to downstream)						
	0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%	
	0	1	2	3	4	
5. Streambank erosion (Each bank)						
	None	fluvial	mass wasting (failures)			
Left	0	1	2			
Right	0	1	2			
6. Streambank instability (Percent of each bank failing)						
	0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%	
Left	0	0.5	1	1.5	2	
Right	0	0.5	1	1.5	2	
7. Established riparian woody-vegetative cover (Each bank)						
	0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%	
Left	2	1.5	1	0.5	0	
Right	2	1.5	1	0.5	0	
8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)						
	0 – 10%	11 – 25%	26 – 50%	51 – 75%	76 – 100%	
Left	0	0.5	1	1.5	2	
Right	0	0.5	1	1.5	2	
9. Stage of channel evolution						
	I	II	III	IV	V	VI
	0	1	2	4	3	1.5

Figure A- 1. Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGAs). The channel stability index is the sum of the values obtained for the nine criteria.

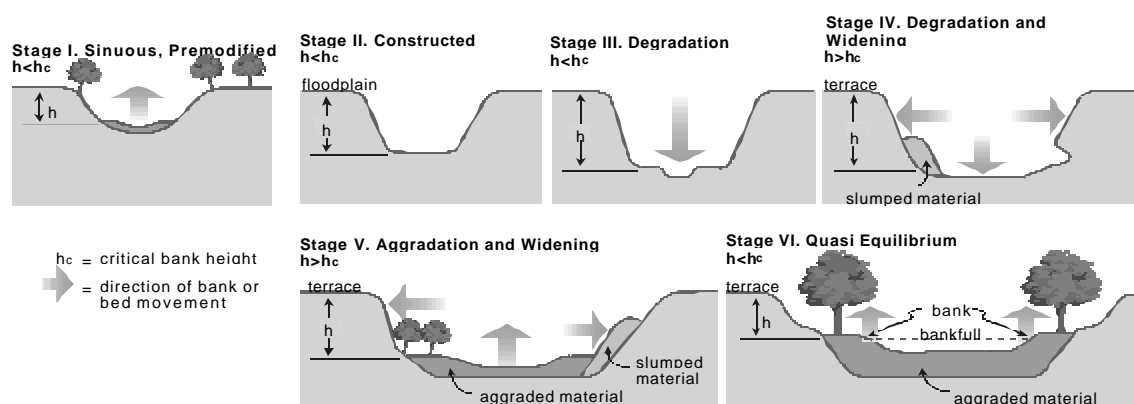


Figure A- 2. Six stages of channel evolution from Simon and Hupp (1986) and Simon (1989b) identifying Stages I and VI as stable, “reference” conditions

Table A- 1. Percentage of fines (embeddedness) for coarse-grained sites along Shades Creek

Dominant bed material type	% Fines	Site	River kilometer
Gravel/Sand	49.7	AZ	51.0
Gravel	36.6	BE	55.1
Boulder/Cobble	35.0	AV	48.3
Boulder/Cobble	33.1	AU	48.1
Gravel	32.4	BX	65.2
Gravel	31.1	DA	84.3
Gravel/Cobble	29.4	CH	70.5
Gravel/Cobble	29.4	CG	70.0
Gravel	23.7	AR	46.4
Gravel	21.0	BT	63.8
Gravel	20.7	O	17.8
Gravel	20.4	BA	52.1
Gravel	16.7	BD	54.6
Gravel	16.0	DC	86.1
Gravel	14.8	BI	57.6
Gravel	14.0	BS	63.3
Gravel	12.9	CO	76.4
Gravel	12.8	BH	57.3
Gravel	12.0	CP	77.1
Gravel	12.0	CD	68.6
Gravel	12.0	BQ	61.9
Boulder/Cobble	12.0	AW	48.8
Gravel	11.8	CE	69.2
Gravel	11.3	AP	45.3
Gravel	10.0	CC	68.3
Gravel	10.0	BZ	67.0
Gravel	9.9	BP	61.3
Gravel/Cobble	9.3	BC	53.9
Gravel	8.1	CF	69.7
Gravel	8.0	CB	68.0
Gravel	6.0	AY	50.2
Gravel	5.0	BY	65.5

Note: Sites exceeding the most stringent reference (4%) are shown in green, while those exceeding the Shades Creek reference (13.4%) are shown in orange and those exceeding the Ridge and Valley reference (16.6%) are shown in yellow.

Table A- 2. Rapid Geomorphic Assessments (RGAs) for Shades Creek

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
DD	86.5	III	Clay	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	17
DC	86.1	V	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	26-50%	26-50%	51-75%	51-75%	26-50%	26-50%	16
DB	85.5	-	-	No	-	-	-	-	-	-	-	-	-	-	-
DA	84.3	V	Gravel	No	51-75%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	76-100%	76-100%	0-10%	11-25%	18.5
CZ	83.3	VI	Gravel	No	26-50%	0-10%	Fluvial	Fluvial	11-25%	11-25%	26-50%	26-50%	0-10%	0-10%	15.5
CY	82.6	V	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	0-10%	0-10%	16
CX	81.8	VI	Bedrock	No	26-50%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	51-75%	0-10%	0-10%	11.5
CW	81.1	V	Bedrock	No	0-10%	0-10%	Mass Wasting	Fluvial	51-75%	26-50%	76-100%	76-100%	51-75%	26-50%	15
CV	80.5	VI	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	11-25%	76-100%	51-75%	0-10%	51-75%	12
CU	80.0	VI	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	51-75%	0-10%	0-10%	13
CT	78.9	VI	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	51-75%	26-50%	51-75%	10.5
CS	78.3	VI	Bedrock	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	26-50%	11-25%	11-25%	11-25%	14
CR	77.8	V	Bedrock	No	51-75%	0-10%	Fluvial	Fluvial	26-50%	11-25%	51-75%	76-100%	51-75%	26-50%	11
CQ	77.6	V	Bedrock	No	0-10%	0-10%	Fluvial	Mass Wasting	0-10%	11-25%	51-75%	11-25%	26-50%	26-50%	15.5
CP	77.1	V	Gravel	No	0-10%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	26-50%	11-25%	76-100%	76-100%	18.5
CO	76.4	VI	Cobble/Gravel	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	26-50%	76-100%	0-10%	0-10%	15.5
CN	75.9	VI	Boulder/Cobble	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	76-100%	26-50%	11-25%	9.5
CM	75.2	II	-	Bed and both banks	-	-	-	-	-	-	-	-	-	-	-
CL	74.0	V	Boulder/Cobble	No	0-10%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	51-75%	26-50%	11-25%	11-25%	18.5
CK	73.1	V	Bedrock	Bed	0-10%	0-10%	Mass Wasting	Fluvial	51-75%	26-50%	26-50%	51-75%	26-50%	51-75%	15.5
CJ	72.5	V	Bedrock/Boulder	Bed	0-10%	0-10%	Fluvial	Mass Wasting	26-50%	26-50%	51-75%	51-75%	26-50%	26-50%	15.5
CI	71.7	V	Bedrock	No	11-25%	0-10%	Fluvial	Mass Wasting	26-50%	26-50%	26-50%	26-50%	26-50%	51-75%	15.5
CH	70.5	II	Gravel	No	0-10%	0-10%	Mass Wasting	Fluvial	0-10%	0-10%	0-10%	0-10%	11-25%	11-25%	18
CG	70.0	V	Gravel/Sand	No	0-10%	11-25%	Mass Wasting	Fluvial	11-25%	11-25%	11-25%	51-75%	0-10%	0-10%	21.5
CF	69.7	V	Boulder/Cobble	No	0-10%	0-10%	None	Mass Wasting	0-10%	76-100%	11-25%	51-75%	76-100%	0-10%	17
CE	69.2	V	Gravel	No	26-50%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	76-100%	76-100%	0-10%	11-25%	17.5
CD	68.6	V	Gravel	No	0-10%	0-10%	Mass Wasting	Fluvial	76-100%	26-50%	76-100%	76-100%	0-10%	11-25%	19.5
CC	68.3	V	Gravel	No	0-10%	0-10%	Fluvial	Mass Wasting	11-25%	26-50%	76-100%	76-100%	0-10%	0-10%	18.5
CB	68.0	V	Gravel	No	11-25%	0-10%	Mass Wasting	Fluvial	26-50%	11-25%	26-50%	51-75%	0-10%	0-10%	19
CA	67.6	V	Gravel	No bed protection, one bank	11-25%	0-10%	Mass Wasting	Fluvial	26-50%	11-25%	51-75%	51-75%	76-100%	76-100%	15.5
BZ	67.0	V	Gravel	No	0-10%	0-10%	Mass Wasting	None	26-50%	0-10%	51-75%	76-100%	11-25%	0-10%	17
BY	65.5	V	Boulder/Cobble	No	11-25%	11-25%	Mass Wasting	Fluvial	51-75%	11-25%	76-100%	26-50%	51-75%	51-75%	16
BX	65.2	V	Gravel	No	26-50%	0-10%	Fluvial	Mass Wasting	11-25%	51-75%	76-100%	51-75%	0-10%	11-25%	17
BW	64.9	V	Sand	No	26-50%	11-25%	Fluvial	Fluvial	11-25%	26-50%	76-100%	76-100%	11-25%	51-75%	15.5
BV	64.4	VI	Bedrock	No	11-25%	0-10%	Fluvial	Fluvial	0-10%	11-25%	51-75%	76-100%	11-25%	51-75%	10.5
BU	64.1	VI	Bedrock	No	11-25%	0-10%	Fluvial	Fluvial	0-10%	11-25%	76-100%	76-100%	0-10%	26-50%	11.5

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Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
BT	63.8	V	Gravel	No	11-25%	0-10%	Mass Wasting	Mass Wasting	76-100%	51-75%	76-100%	76-100%	0-10%	0-10%	20.5
BS	63.3	V	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	26-50%	76-100%	76-100%	0-10%	26-50%	15.5
BR	62.9	VI	Gravel	No	0-10%	0-10%	Fluvial	Fluvial	11-25%	11-25%	76-100%	76-100%	11-25%	0-10%	15
BQ	61.9	VI	Cobble/Gravel	No	26-50%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	76-100%	11-25%	51-75%	11.5
BP	61.3	VI	Gravel	No	76-100%	0-10%	Fluvial	None	26-50%	0-10%	26-50%	51-75%	11-25%	51-75%	10
BO	60.8	VI	Bedrock/Boulder	No	51-75%	0-10%	Fluvial	Fluvial	26-50%	26-50%	26-50%	76-100%	0-10%	26-50%	11.5
BN	60.1	VI	Bedrock	No	11-25%	0-10%	None	Fluvial	0-10%	11-25%	51-75%	76-100%	0-10%	11-25%	11
BM	59.6	V	Boulder/Cobble	No	51-75%	0-10%	None	Mass Wasting	11-25%	76-100%	51-75%	0-10%	76-100%	11-25%	14.5
BL	58.8	V	Cobble/Gravel	No	51-75%	0-10%	Mass Wasting	Fluvial	26-50%	11-25%	26-50%	51-75%	0-10%	11-25%	15.5
BK	58.5	VI	Bedrock/Gravel	No	26-50%	0-10%	None	None	11-25%	11-25%	11-25%	11-25%	51-75%	51-75%	10.5
BJ	58.0	VI	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	26-50%	76-100%	12.5
BI	57.6	V	Gravel	No	26-50%	0-10%	Fluvial	Mass Wasting	11-25%	51-75%	51-75%	51-75%	11-25%	11-25%	17.5
BH	57.3	V	Gravel	No	26-50%	0-10%	Fluvial	Fluvial	26-50%	26-50%	51-75%	51-75%	11-25%	11-25%	16.5
BG	56.7	I	Boulder/Cobble	No	11-25%	0-10%	Fluvial	None	0-10%	0-10%	26-50%	11-25%	51-75%	0-10%	11
BF	56.2	I	Bedrock/Boulder	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	51-75%	0-10%	11
BE	55.1	I	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	11-25%	11-25%	13
BD	54.6	V	Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	11-25%	51-75%	76-100%	0-10%	16
BC	53.9	II	Cobble/Gravel	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	26-50%	51-75%	76-100%	76-100%	11
BB	53.1	V	Gravel/Sand	No	26-50%	0-10%	Fluvial	Mass Wasting	11-25%	76-100%	51-75%	11-25%	76-100%	26-50%	17
BA	52.1	V	Gravel	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	76-100%	26-50%	51-75%	26-50%	12.5
AZ	51.0	V	Gravel/Sand	No	11-25%	0-10%	Fluvial	Fluvial	26-50%	26-50%	26-50%	26-50%	76-100%	51-75%	16
AY	50.2	V	Gravel	No	26-50%	0-10%	Fluvial	Fluvial	26-50%	11-25%	51-75%	51-75%	76-100%	51-75%	13
AX	49.9	V	Sand	No	11-25%	0-10%	Fluvial	Fluvial	26-50%	11-25%	51-75%	51-75%	51-75%	26-50%	16
AW	48.8	V	Boulder/Cobble	No	26-50%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	51-75%	51-75%	11-25%	11-25%	18
AV	48.3	V	Boulder/Cobble	No	11-25%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	76-100%	76-100%	26-50%	26-50%	17
AU	48.1	V	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	76-100%	51-75%	26-50%	26-50%	26-50%	26-50%	22.5
AT	47.6	II	Bedrock	Bed and both banks	0-10%	0-10%	None	None	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	16
AS	47.0	VI	Sand	No	11-25%	0-10%	Fluvial	Fluvial	11-25%	11-25%	76-100%	76-100%	51-75%	51-75%	12.5
AR	46.4	V	Gravel	No	26-50%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	11-25%	11-25%	76-100%	51-75%	19.5
AQ	45.6	V	Sand	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	26-50%	51-75%	51-75%	0-10%	11-25%	16
AP	45.3	V	Gravel	No	51-75%	0-10%	Mass Wasting	Fluvial	76-100%	0-10%	11-25%	51-75%	76-100%	0-10%	16
AO	44.6	V	Boulder/Cobble	No	0-10%	0-10%	Fluvial	Fluvial	11-25%	11-25%	76-100%	76-100%	26-50%	0-10%	15
AN	44.2	V	Boulder/Cobble	No	0-10%	0-10%	Fluvial	Fluvial	26-50%	26-50%	76-100%	76-100%	26-50%	26-50%	15
AM	43.3	VI	Bedrock	No	11-25%	0-10%	None	Fluvial	0-10%	11-25%	0-10%	76-100%	0-10%	51-75%	11.5
AL	42.7	V	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	51-75%	51-75%	26-50%	51-75%	19.5
AK	41.6	V	Sand/Silt Clay	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	26-50%	51-75%	51-75%	76-100%	13.5
AJ	41.2	V	Sand	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	76-100%	76-100%	76-100%	11.5
AI	40.7	V	Sand	No	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	26-50%	51-75%	76-100%	76-100%	14.5
AH	39.6	V	Sand	No	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	0-10%	11-25%	76-100%	76-100%	16.5
AG	35.2	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	26-50%	76-100%	51-75%	51-75%	51-75%	0-10%	19.5

Draft TMDL for Shades Creek: Siltation, Turbidity and Habitat Alteration October 2003

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
AF	31.6	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	11-25%	0-10%	76-100%	76-100%	18.5
AE	29.5	V	Gravel/Sand	No	26-50%	26-50%	None	Mass Wasting	11-25%	76-100%	76-100%	11-25%	76-100%	11-25%	18
AD	27.9	V	Sand	No	11-25%	0-10%	Mass Wasting	Mass Wasting	26-50%	51-75%	26-50%	11-25%	51-75%	51-75%	20
AC	25.3	V	Sand	No	51-75%	0-10%	Mass Wasting	Mass Wasting	76-100%	26-50%	11-25%	51-75%	11-25%	76-100%	18.5
AB	24.5	V	Cobble/Gravel	No	26-50%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	11-25%	26-50%	76-100%	26-50%	16
AA	24.3	V	Cobble/Gravel	No	51-75%	0-10%	None	Mass Wasting	0-10%	51-75%	76-100%	26-50%	76-100%	51-75%	11.5
Z	24.1	V	Sand/Silt Clay	No	76-100%	0-10%	Fluvial	Fluvial	11-25%	26-50%	11-25%	26-50%	76-100%	76-100%	13.5
Y	23.8	V	Bedrock	No	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	0-10%	26-50%	76-100%	76-100%	76-100%	10.5
X	22.9	I	Bedrock	No	51-75%	0-10%	Fluvial	Fluvial	26-50%	11-25%	26-50%	51-75%	51-75%	51-75%	8
W	22.6	VI	Sand	No	76-100%	0-10%	Fluvial	Mass Wasting	0-10%	26-50%	76-100%	51-75%	51-75%	51-75%	11
V	21.4	V	Bedrock	No	11-25%	0-10%	Mass Wasting	Mass Wasting	51-75%	76-100%	51-75%	76-100%	26-50%	26-50%	17
U	21.0	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	76-100%	76-100%	26-50%	26-50%	19
T	20.5	I	Bedrock	No	11-25%	0-10%	Fluvial	Fluvial	76-100%	51-75%	76-100%	26-50%	51-75%	51-75%	11.5
S	19.7	VI	Boulder/Cobble	No	11-25%	0-10%	Fluvial	Fluvial	26-50%	26-50%	76-100%	51-75%	26-50%	0-10%	14
R	19.3	VI	Bedrock	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	11-25%	76-100%	51-75%	11-25%	51-75%	9
Q	19.0	V	Sand	No	51-75%	0-10%	Mass Wasting	None	51-75%	0-10%	51-75%	11-25%	0-10%	11-25%	17
P	18.1	V	Bedrock	No	76-100%	11-25%	Fluvial	Fluvial	26-50%	11-25%	51-75%	76-100%	11-25%	11-25%	12
O	17.8	I	Gravel	No	76-100%	0-10%	Fluvial	Fluvial	26-50%	11-25%	11-25%	76-100%	0-10%	11-25%	11.5
N	17.4	V	Bedrock	No	76-100%	0-10%	Mass Wasting	Fluvial	76-100%	11-25%	51-75%	51-75%	51-75%	0-10%	13
M	16.8	I	Bedrock/Boulder	No	0-10%	0-10%	None	Fluvial	0-10%	26-50%	11-25%	11-25%	0-10%	11-25%	14
L	16.3	I	Bedrock	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	11-25%	11-25%	9
K	15.8	I	Bedrock/Boulder	No	76-100%	0-10%	Fluvial	Fluvial	11-25%	0-10%	76-100%	51-75%	0-10%	11-25%	8
J	15.4	I	Bedrock/Boulder	No	76-100%	0-10%	Fluvial	Fluvial	11-25%	0-10%	76-100%	76-100%	26-50%	51-75%	5.5
I	14.7	I	Bedrock/Boulder	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	51-75%	0-10%	5
H	13.8	I	Boulder/Cobble	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	51-75%	76-100%	4.5
G	13.2	I	Boulder/Cobble	No	26-50%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5
F	12.7	I	Bedrock	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	26-50%	26-50%	5
E	12.1	I	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	6
D	11.6	I	Bedrock	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	6
C	11.4	I	Bedrock/Boulder	No	76-100%	0-10%	None	Fluvial	0-10%	11-25%	51-75%	26-50%	0-10%	26-50%	9
B	11.1	I	Boulder/Cobble	No	76-100%	0-10%	Fluvial	Fluvial	11-25%	0-10%	76-100%	76-100%	0-10%	11-25%	8
A	10.0	I	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	26-50%	0-10%	5